Fo 4

(12) UK Patent Application (19) GB (11) 2 326 017 (13) A

(43) Date of A Publication 09.12.1998

(21) Application No 9811462.2

(22) Date of Filing 29.05.1998

(30) Priority Data
(31) 08868330 (32) 03.06.1997 (33) US

(51) INT CL^6
H01M 8/02

(52) UK CL (Edition P)
H1B BF10 BF402

(56) Documents Cited
GB 2158988 A WO 97/50139 A US 5733678 A

(58) Field of Search
UK CL (Edition P) H1B
INT CL^6 H01M 8/00
On line databases WPI,EDOC,JAPIO

(71) Applicant(s)
Motorola Inc
(Incorporated in USA - Delaware)
Corporate Offices, 1303 East Algonquin Road, Schaumburg, Illinois 60196, United States of America

(72) Inventor(s)
James Lynn Davis

(74) Agent and/or Address for Service
Marc Morgan
Motorola Limited, European Intellectual Property Operation, Midpoint, Alencon Link, BASINGSTOKE, Hampshire, RG21 7PL, United Kingdom

(54) Abstract Title
Bipolar plate for fuel cell assembly

(57) A fuel cell assembly has thermoplastic bipolar plates sandwiched between a number of electrode assemblies (30, 30') to form a stack. A bipolar plate (35) alternates with an electrode assembly (30) so that one side (31)of the plate is adjacent and adhesively bonded to the corresponding surface of one electrode assembly anode (34), and the other side (39) is adjacent and adhesively bonded to the corresponding surface of a cathode (32) in the neighboring electrode assembly (30'). The adhesive bonding also serves to seal the fuel and oxidant channels (37).

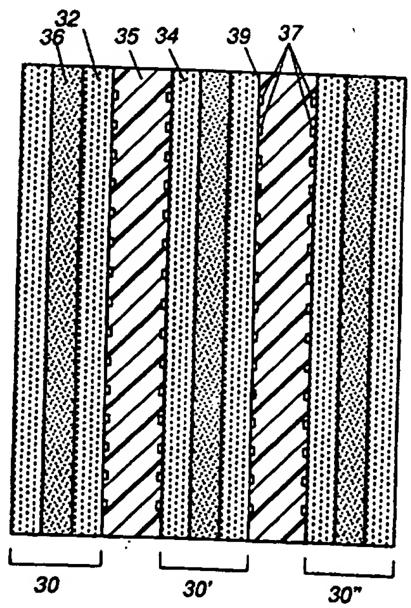

FIG. 3

GB 2 326 017 A

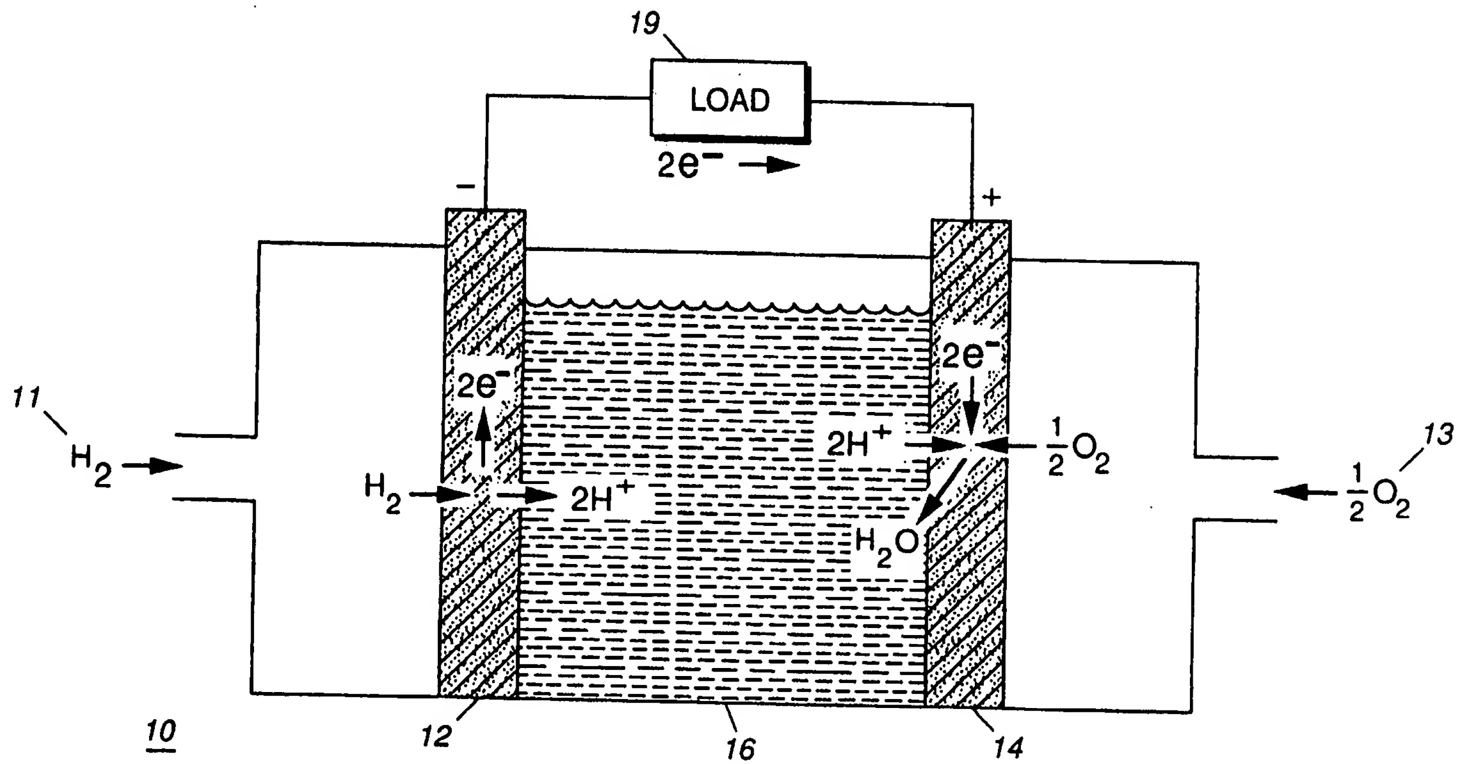

FIG. 1
(PRIOR ART)

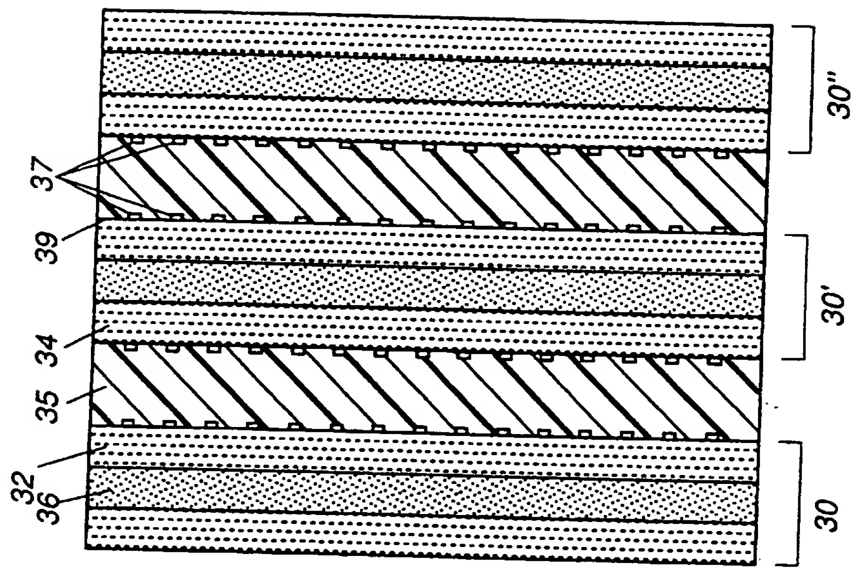

FIG. 3

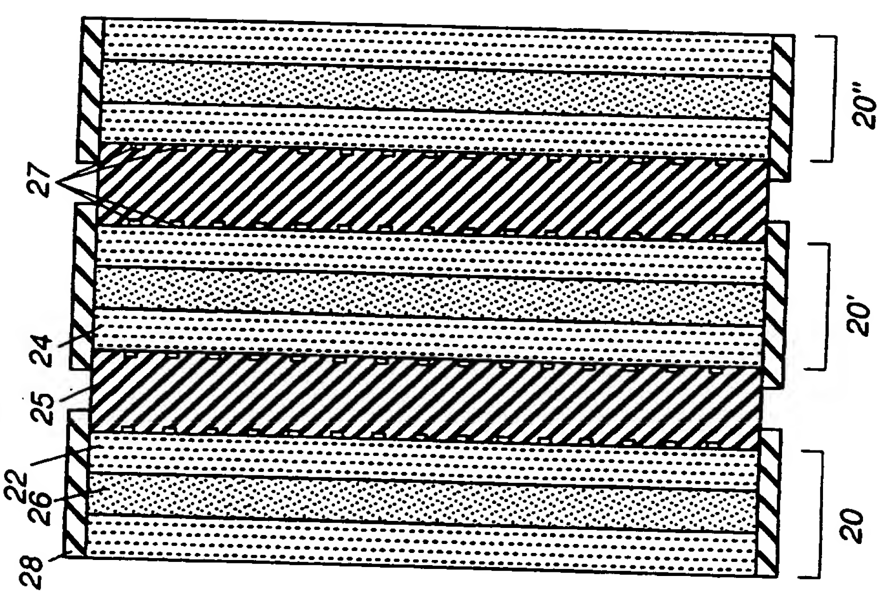

FIG. 2
(PRIOR ART)

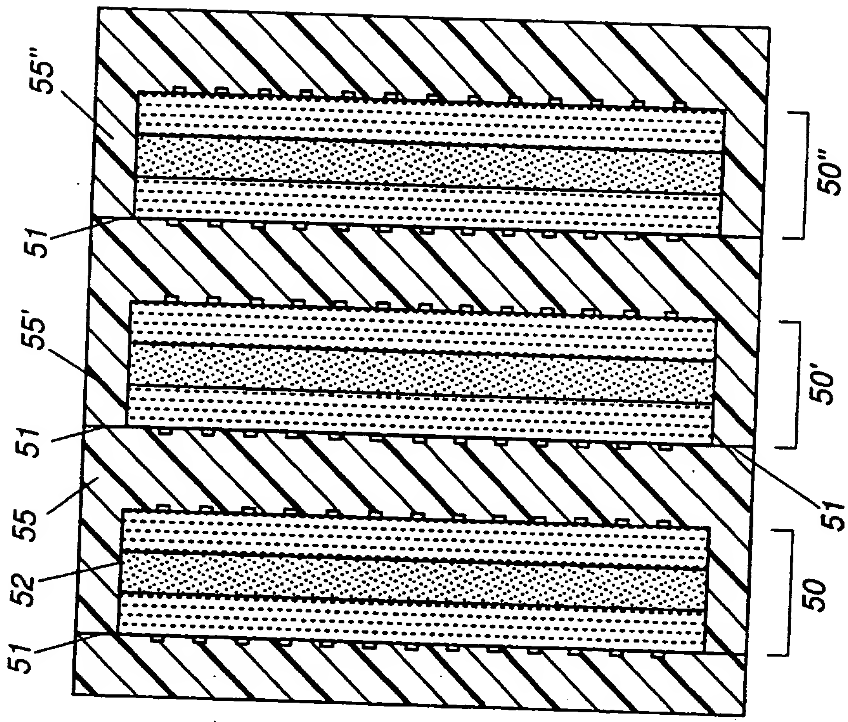

FIG. 5

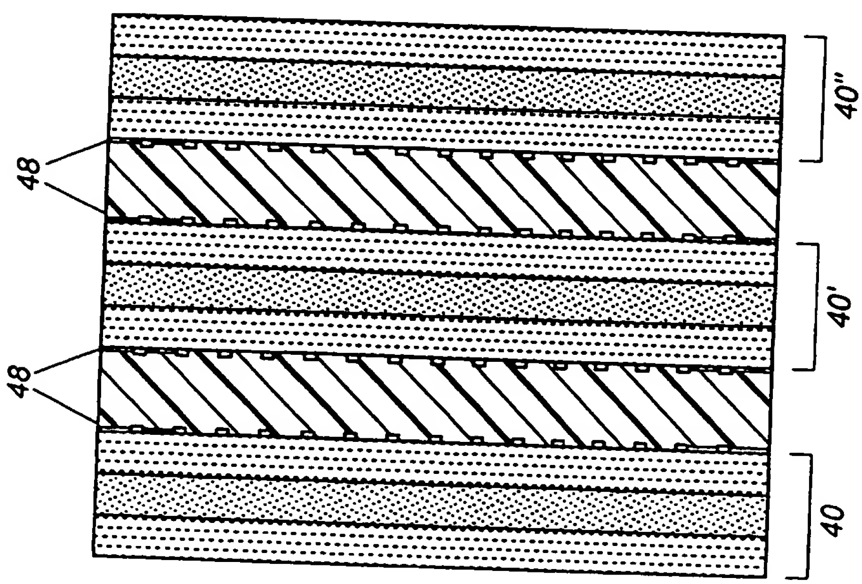

FIG. 4

2326017

BIPOLAR PLATE FOR FUEL CELL ASSEMBLY

TECHNICAL FIELD

This invention relates in general to fuel cells, and more particularly to a bipolar plate for fuel cells.

BACKGROUND

Fuel cells are electrochemical cells in which a free energy change resulting from a fuel oxidation reaction is converted into electrical energy. As shown in FIG. 1, a typical fuel cell 10 consists of a fuel electrode (anode) 12 and an oxidant electrode (cathode) 14, separated by an ion-conducting electrolyte 16. The electrodes are connected electrically through a load (such as an electronic circuit) 19 by an external circuit conductor. In the circuit conductor, electric current is transported by the flow of electrons, whereas in the electrolyte it is transported by the flow of ions, such as the hydrogen ion (H^+) in acid electrolytes, or the hydroxyl ion (OH^-) in alkaline electrolytes. In theory, any substance capable of chemical oxidation that can be supplied continuously (as a gas or fluid) can be oxidized galvanically as the fuel 11 at the anode 12 of a fuel cell. Similarly, the oxidant 13 can be any material that can be reduced at a sufficient rate. For specialized systems, both reactants might be liquids, such as hydrazine for the fuel and hydrogen peroxide or nitric acid for the oxidant. Gaseous hydrogen has become the fuel of choice for most applications, because of its high reactivity in the presence of suitable catalysts and because of its high energy density when stored as a cryogenic liquid, such as for use in space. Similarly, at the fuel cell cathode 14 the most common oxidant is gaseous oxygen, which is readily and economically available from the air for fuel cells used in terrestrial applications. When gaseous hydrogen and oxygen are used as fuel and oxidant, the electrodes are porous to permit the gas-electrolyte junction to be as great as possible. The electrodes must be electronic conductors, and possess the

appropriate reactivity to give significant reaction rates. The most common fuel cells are of the hydrogen-oxygen variety that employ an acid electrolyte. At the anode 12, incoming hydrogen gas 11 ionizes to produce hydrogen ions and electrons. Since the electrolyte is a non-electronic conductor, the electrons flow away from the anode via the metallic external circuit. At the cathode 14, oxygen gas 13 reacts with the hydrogen ions migrating through the electrolyte 16 and the incoming electrons from the external circuit to produce water as a byproduct. Depending on the operating temperature of the cell, the product water may enter the electrolyte, thereby diluting it and increasing its volume, or be extracted through the cathode as vapor. The overall reaction that takes place in the fuel cell is the sum of the anode and cathode reactions; in the present case, the combination of hydrogen with oxygen to produce water, with part of the free energy of reaction released directly as electrical energy. The difference between this available free energy and the heat of reaction is produced as heat at the temperature of the fuel cell. In any event, it can be seen that as long as hydrogen and oxygen are fed to the fuel cell, the flow of electric current will be sustained by electronic flow in the external circuit and ionic flow in the electrolyte.

In practice, a number of fuel cells are normally stacked or 'ganged' together to form a fuel cell assembly. Referring now to FIG. 2, the anode/electrolyte/cathode sub-unit is typically referred to as an 'electrode assembly' (EA). The cathode 24 of a first EA 20 is typically disposed next to the anode 22 of a subsequent EA 20', but separated by a bipolar plate 25. In the prior art, the bipolar plate is typically carbon, chosen for its unique combination of properties; chemical inertness, electrical conductivity, rigidity and the ability to be machined. A network of channels 27 are typically formed in the bipolar plate by mechanical machining. These grooves or channels provide distribution of the gaseous or liquid fuel and oxidant to the anode and cathode respectively. The bipolar plate provides electrical connection from one EA to the next, and also serves to isolate the anode fuel from the cathode oxidant in adjacent EA's. In order to further contain the fuel and keep it

separate from the oxidant, a sealing means 28, such as an o-ring or other exterior gasket, must be provided. As can be easily appreciated, the cost of fabricating the carbon bipolar plate and then assembling it into the fuel cell assembly is significant, due to the materials and labor involved. Consequently, this is one of the factors preventing widespread acceptance of fuel cell technology. A low cost bipolar plate would be a significant addition to the field.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is schematic representation of a typical fuel cell as practiced in the prior art.

FIG. 2 is a schematic cross sectional view of a fuel cell assembly as practiced in the prior art.

FIG. 3 is a schematic cross sectional view of a fuel cell assembly in accordance with the invention.

FIG. 4 is a schematic cross sectional view of an alternate embodiment of a fuel cell assembly in accordance with the invention.

FIG. 5 is a schematic cross sectional view of an another embodiment of a fuel cell assembly in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A fuel cell assembly has thermoplastic bipolar plates sandwiched between a number of electrode assemblies to form a stack. A thermoplastic bipolar plate alternates with an electrode assembly so that one side of the plate is adjacent to the corresponding surface of one electrode assembly anode, and the other side is adjacent to the corresponding surface of a cathode in the neighboring electrode assembly. The thermoplastic bipolar plate is adhesively bonded to each of the adjacent electrode assemblies, sealing the fuel and oxidant channels while eliminating the need for additional gaskets or seals.

Referring now to FIG. 3, a fuel cell assembly consists of a fuel cell stack containing more than one electrode assembly 30, 30', 30". As used in the context of this discussion and elsewhere in the literature, an

electrode assembly (EA) or membrane electrode assembly (MEA) is a unit cell consisting of an anode 32, a cathode 34 and an electrolyte 36. When a plurality of these unit cells are connected together, they are known as a fuel cell stack or a fuel cell assembly. In my preferred embodiment, the electrolyte is a polymer electrolyte membrane (PEM), such as those typically used in hydrogen fuel cell, a direct methanol PEM cell, or a PEM fuel cell using an organic fuel such as ethanol or formaldehyde. PEMs are ionic polymers having very high ion conductivity. The polymeric nature of PEMs makes them much easier to handle than liquid electrolytes. The physical construction of the electrochemical cell is greatly simplified since elaborate seals and containment systems are not needed to contain corrosive liquid electrolytes. A PEM should have the following properties: (1) high ionic conductivity, (2) zero electronic conductivity, (3) very low permeability to gases, (4) chemical stability at the operating temperature, (5) mechanical strength, (6) low sensitivity to humidity, and (7) compatibility with catalyst. Fuel cells employing PEMs are described and known in the literature, for example, U.S. Patent No. 5,403,675, and since one of ordinary skill in the art is assumed to be familiar with PEM cells, PEMs will not be further elaborated upon here. Between each of the unit cells in the stack is an electrically conductive, thermoplastic bipolar plate 35 to provide electrical conductivity from the cathode 34 of one fuel cell 30 to the anode 32 of the neighboring fuel cell 30'. Each cathode in the stack is isolated from the previous anode by the bipolar plate. A fuel cell stack can be created by alternating the unit cells with the bipolar plates in a fashion where n (n being an integer greater than 2) electrode assemblies are combined with n-1 bipolar plates to create the fuel cell stack. Of course, one skilled in the art will realize that the fuel cell stack should also contain end caps over the outermost electrodes, which are not shown in FIGs. 2-4 for the sake of clarity.

The thermoplastic bipolar plate is rendered electrically conductive through any one of a number of methods known to those skilled in the art. For example, an electrically conductive filler such as carbon

powder, carbon fiber or metal particles such as powders or flakes (for example, titanium, aluminum, stainless steel, silver, gold, etc.) can be added to the thermoplastic. In addition, the thermoplastic bipolar plate can be rendered electrically conductive by coating the surface with a thin film of a conductive material such as carbon, gold, nickel, titanium, silver, platinum, palladium, chrome or rhodium, as is well known in the electroplating and thin film vacuum deposition arts. In this case, the edges of the bipolar plate must also be treated in order to insure that the plate is able to conduct the electrical charge between the neighboring cathodes and the anodes. If the plastic is completely metallized on the outside, then the conductive path is from the anode side around the plate to the cathode side, not through the plastic. In order words, the two sides or faces of the bipolar plate are shorted together via the metallization along the edges.

Turning now to materials selection, the thermoplastic bipolar plate can be any number of plastics such as commodity thermoplastics like polyethylene, polypropylene or polyacrylate, or it can be an engineering thermoplastic such as polycarbonate, acrylonitrile-butadiene-styrene (ABS), polyetherimide, polyimide or polyamide. In general, the lower cost commodity thermoplastics are preferred, as they will result in a lower cost fuel cell assembly, however, other performance criteria such as temperature or chemical resistance may dictate the need for a higher performance material. Treating these materials to make them electrically conductive can easily be accomplished by filling or coating, as explained above.

A plurality of channels or grooves 37 are formed in the surface of the thermoplastic bipolar plate to provide for gas distribution to the anode and cathode. Although these channels are typically formed in the carbon plates of prior art by mechanical machining, I have found that when using thermoplastics, they can by formed in the surface by several methods that are more efficient and less costly, such as embossing, molding, thermoforming, photolithography using a photo active layer, micromachining, or incorporation of a stainless steel screen in the

surface. Shimshon Gottesfeld et al. of Los Alamos National Laboratories have demonstrated a useful method of embedding a mesh matrix in a material to form channels or pockets.

When a thermoplastic material that has a relatively low melt flow index, such as polyethylene or polypropylene, is used as the bipolar plate, the plate can then be easily laminated directly to the MEA by applying heat and pressure to fuse it to the cathode 34 or anode 32. This method of fusing eliminates the need for external gaskets or seals, and serves to seal the gas distribution channels 37 from each other, thus providing mechanical rigidity and integrity to the fuel cell stack and sealing it in a single step. This reduces the cost and size of the fuel cell stack by eliminating gaskets, their attendant cost and size, and eliminates the need for expensive machined carbon blocks.

In an alternate embodiment of the invention as shown in FIG. 4, the bipolar plate is a higher melting thermoplastic, and a thin layer of a thermoplastic material 48 that has a relatively low melt flow index, such as polyethylene or polypropylene, is applied to the plate. The polyethylene or polypropylene then serves to laminate the MEA to the bipolar plate by applying heat and pressure to fuse it to the cathode 34 or anode 32. Care must be taken so as not to block the gas distribution channels with the thin layer of the bonding thermoplastic. In addition, electrical conductivity must be maintained between an electrode and the bipolar plate, so the thin layer of thermoplastic material 48 must be selectively disposed in specific locations so that the electrical conductivity is preserved. Further, the thin layer of thermoplastic material 48 can optionally be rendered electrically conductive by filling it with conductive particles in a manner similar to that used to render the base plate conductive.

In another embodiment of the invention, an adhesive can be used in place of the thin layer of thermoplastic material 48 to provide the necessary mechanical bonding of the bipolar plate to the MEA. For example, a B-staged epoxy can be disposed on the surface of the bipolar plate, and the plate adhered to the MEA by means of heat and pressure to

cure the epoxy. Hot melt adhesives are also useful as adhesive agents, and they can be disposed on the surface in a number of ways, and then assembled to form the stack. Reference numeral 48 in FIG. 4, while previously described as a thin layer of thermoplastic material, is also intended to show how the epoxy or hot melt adhesive is applied to the bipolar plate/MEA stack. Optionally, if a B-staged epoxy is used, the gas distribution channels can be formed in the adhesive layer by mechanical or photolithographic methods.

Referring now to FIG. 5, the thermoplastic bipolar plate can also be fabricated in forms other than planar. The very nature of the thermoplastic material lends itself well to creating bipolar plates in a variety of shapes. For example, the plate 55 can be made to have a cavity or recess 52 on one side. The interior of the recess 52 is made conductive by, for example, coating the surface at the bottom of the recess with a conductive metal (electroplating, or by vacuum deposition). The opposite side is also rendered conductive. To assemble the fuel cell stack, the MEAs 50 are placed inside the recesses 52 so that the one electrode of each MEA is touching the conductive coating in the recess. The electrode is preferably bonded to the MEA in a fashion previously described. These subassemblies are the stacked together to create a stack shown in FIG. 5, where one thermoplastic bipolar plate is bonded directly to another bipolar plate by fusing an unmetallized portion 51 near the edges of the bipolar plate. This seals the gases in and holds the assembly together without the need for gaskets or external fasteners. Thus, a fuel cell stack is made by combining a plurality of MEAs (50, 50', 50") with a plurality of shaped thermoplastic bipolar plates (55, 55', 55").

In summary, a PEM fuel cell assembly has been described that uses a thermoplastic bipolar plate to connect the individual MEAs together. The bipolar plate utilizes low cost materials, and is adhesively bonded to the MEAs, thus eliminating the need for gaskets and other sealing means. The size of the assembly is reduced along with the cost.

While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not so limited, and other equivalents will occur to those skilled in the art without departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

CLAIMS

1. A fuel cell assembly, comprising:

two electrode assemblies having an anode and a cathode separated by an electrolyte;

a bipolar plate, comprising an electrically conductive thermoplastic polymer substrate having two opposing major faces with a plurality of channels formed on each face; and

the bipolar plate disposed between the two electrode assemblies such that one major face is adjacent and adhesively bonded to a major surface of the first electrode assembly anode and the other major face is adjacent and adhesively bonded to a major surface of the second electrode assembly cathode.

2. The fuel cell assembly as described in claim 1, further comprising an additional layer of thermoplastic situated between the major face and the cathode, said layer being heat fused to the bipolar plate and the cathode.

3. The fuel cell assembly as described in claim 1, further comprising an adhesive layer situated between the major face and the cathode, said adhesive layer bonding the bipolar plate to the cathode.

4. The fuel cell assembly as described in claim 1, wherein the electrolyte is a polymer electrolyte membrane.

5. A fuel cell assembly, comprising:

a plurality of n membrane electrode assemblies each having an anode and a cathode separated by a polymer electrolyte membrane;

a plurality of n-1 bipolar plates, each plate comprising:

a thermoplastic polymer substrate selected from the group consisting of polyethylene, polypropylene, polycarbonate, acrylonitrile-butadiene-styrene, polyetherimide, polyimide, polyamide, and polyacrylate;

the substrate having two opposing major faces with a plurality of fuel channels formed on one face and a plurality of oxidant channels formed on the other face; and

the thermoplastic polymer substrate rendered electrically conductive by filling it with a metal or carbon filler;

the plurality of n-1 bipolar plates and the plurality of n membrane electrode assemblies assembled in a stack such that a bipolar plate alternates with a membrane electrode assembly, each bipolar plate adhesively bonded to two corresponding membrane electrode assemblies, said adhesive bond also serving to seal the plurality of fuel channels and the plurality of oxidant channels.

The Patent Office

H

Application No: GB 9811462.2
Claims searched: All claims

Examiner: A.R.Martin
Date of search: 10 July 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H1B

Int Cl (Ed.6): H01M 8/00

Other: On line databases WPI,EDOC,JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	US5733678 A	Fraunhofer see claim 20	Claims 1 and 5 at least
Y	WO97/50139 A	Du Pont see page 3 lines 25-35	"
Y	GB2158988 A	Alsthom see page 3 lines 1-4	"

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.